

# FISHERY RESEARCH



## **KOOTENAI RIVER FISHERIES INVESTIGATION: STOCK STATUS OF BURBOT**

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## ABSTRACT

We studied the  $H_0$  hypothesis that winter discharge for power production does not inhibit burbot *Lota lota* migration to spawning tributaries in the Kootenai River. We anticipated three minimum discharge (113 m/s) periods from Libby Dam of five days each in November and December 1996 and January 1997. We captured 23 burbot in the Kootenai River, Idaho, and British Columbia (BC), Canada, only two of which were caught in Idaho. Burbot catch averaged 0.02 fish/net day. Burbot ranged from 450 to 743 mm total length and weighed from 700 to 2,700 g (mean=1,323 g). Nine burbot were implanted with sonic transmitters and most were released at the capture locations. Two additional burbot had active transmitters from the previous season. Burbot were located 447 times. Only two burbot were monitored during the first test in November 1996, which lasted three days. Both burbot moved, but burbot 374 moved upstream during the ramp up period after the flow test and returned downstream to its original location after flows exceeded 425 m<sup>3</sup>/s. The second burbot could not be relocated. The second test in December was also brief and did not result in any conclusive findings. A third test scheduled in January was denied. Ripe burbot were captured at the mouth of the Goat River during February. Sampling for burbot eggs and larvae in the Goat River resulted in the catch of a single egg of an unknown species. Analysis of mtDNA variation from burbot sampled from three locations in the Kootenai River revealed seven composite mtDNA haplotypes. Two haplotypes were common to all samples. Analysis indicated the burbot stock in Idaho/BC is genetically distinct from burbot in the Kootenai River, MT. This study was a cooperative effort with the BC Ministry of Environment.

## INTRODUCTION

Burbot *Lota lota* in the Kootenai River once provided an important winter fishery to residents of northern Idaho (Paragamian 1994; Figure 1). Some anglers reported catching over 40 burbot a night during winter setline fishing (Paragamian 1994). The annual harvest of burbot from the Kootenai River by sport and commercial fisherman in Idaho was estimated at approximately 22,700 kg (50,000 lbs; Ned Horner, Regional Fisheries Manager, personal communication). Burbot caught during the winter fishery are thought to have been part of a spawning migration from the lower river and Kootenay Lake, BC, Canada. However, after construction and operation of Libby Dam in 1972, the fishery rapidly declined until it was closed in the early 1990s. Concomitant to the collapse in Idaho was the collapse of the burbot fishery in Kootenay Lake, BC (Paragamian 1993).

Operation of Libby Dam for hydroelectric power and flood control has created major changes in the hydrograph (Figure 2), temperature regime, and nutrient supply of the Kootenai River (Paragamian 1993; 1994; and 1996; Snyder and Minshall 1996; and Richards 1996).

Preliminary study of burbot in the Kootenai River began in 1978 (Partridge 1983) but was secondary to a white sturgeon *Acipenser transmontanus* project. Partridges' study documented abundance, movement, harvest, and age structure of burbot. The Kootenai River Fisheries Investigations were a follow-up to the earlier study.

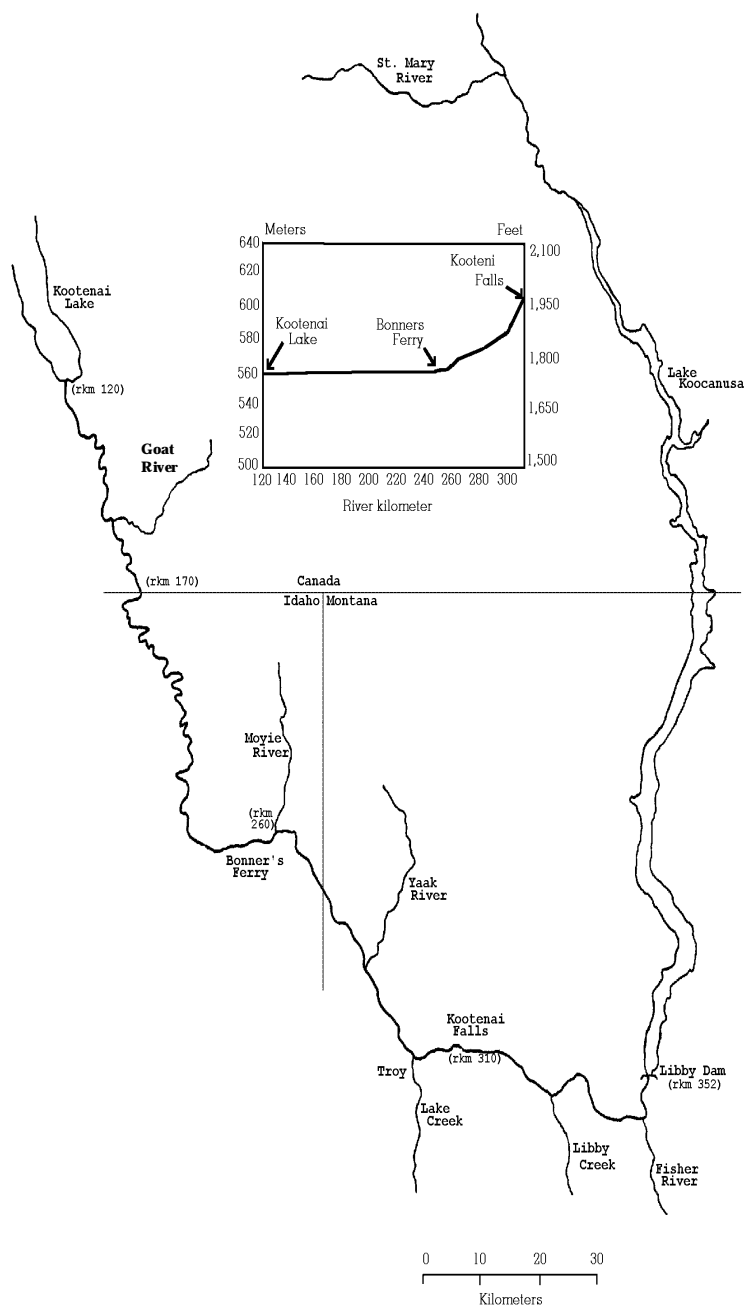


Figure 1. Location of the Kootenai River, Kootenay Lake, Lake Kooconusa, and major tributaries in Idaho. The river distances in Figure 1 are in kilometers (rkm) and are indicated at important access points.



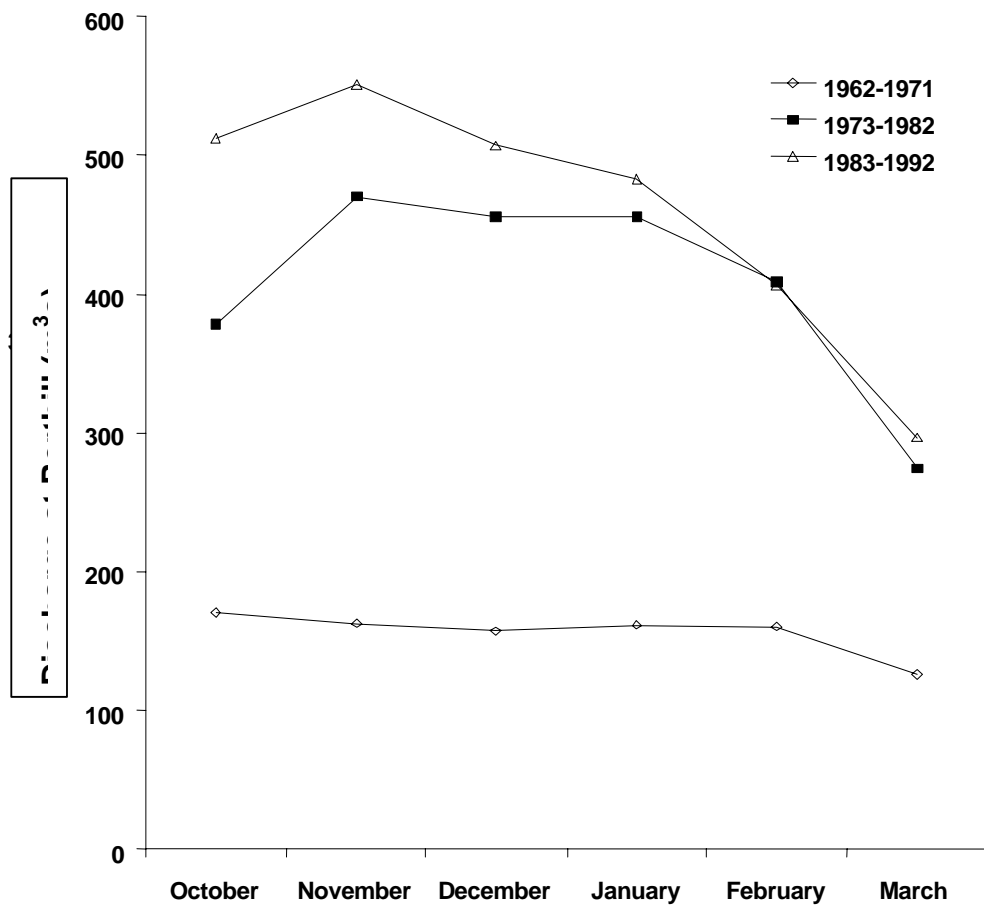


Figure 2. Mean monthly discharge of the Kootenai River at Porthill, Idaho, from 1962 through 1971 (pre-Libby Dam), from 1973 through 1982, and 1983 through 1992 (post-Libby Dam)

The Kootenai River Fisheries Investigation was initiated in 1993 to address burbot abundance, distribution, size structure, reproductive success, movement, and to identify factors limiting burbot in the Kootenai River. Few burbot were captured between river kilometer (rkm) 244 and the Montana border (rkm 275). There has been little evidence of burbot reproduction in Idaho. Only one juvenile burbot was captured from 1993 to 1996 and no larval fish have been collected. However, in our catch we found numerous age groups indicating some burbot were reproducing successfully somewhere. Previous studies have failed to document a spawning run of burbot from the lower river or Kootenay Lake, but cooperative sampling in the BC reach of the river indicated there was a spawning run of burbot entering the Goat River.

Burbot were captured in Idaho and British Columbia prior to the spawning seasons from 1994 through 1996 and implanted with sonic transmitters. Telemetry of burbot during the winters of 1994-1995, and 1995-1996, indicated high velocities (>24 cm/s) produced during winter operation may be inhibiting spawning migration to Idaho. Ripe burbot were captured at the Goat River but few burbot were caught in the Kootenai River upstream from here, and no burbot have been tracked upstream into Idaho waters before the end of the spawning season.

## **GOAL**

Restore the burbot population in the Idaho reach of the Kootenai River and improve fishing success to historic levels.

## **OBJECTIVES**

1. Identify factors limiting burbot within the Idaho portion of the Kootenai River drainage and recommend management alternatives to restore the population to a self-sustained fishable level.
2. Define factors limiting burbot reproductive success to improve survival and recruitment of young burbot.
3. Identify possible genetic differences in Kootenai River burbot samples collected from two locations in Montana and samples taken from the river in Idaho and British Columbia.

## STUDY AREA

The Kootenai River (spelled Kootenay for Canadian waters) is the second largest tributary to the Columbia River. Originating in Kootenay National Park, BC, the river flows south into Montana where Libby Dam impounds water back into Canada forming Lake Koocanusa (Figure 1). From Libby Dam the river turns west then northwest into Idaho then north into BC and Kootenay Lake. The Kootenai River at Porthill, Idaho drains about 35,490 km<sup>2</sup>. The reach in Idaho is 106 km long. Kootenay Lake drains out the West Arm and eventually the river joins the Columbia River near Castlegar, BC.

The Kootenai River in Idaho presents three different channel and habitat types. As the river enters Idaho, it is typified by steep canyon walls and a gradient of about 0.6 m/km. About 1 km below the Moyie River, the river begins a short braided reach, then at Bonners Ferry the river changes to a lower gradient of about 0.02 m/km and meanders through a broad flood plain. Tributary streams of the Kootenai River are typically high gradient as they pass through mountain canyons but revert to lower gradients when they reach the valley floor where most have been channelized.

## METHODS

### Kootenai River Discharge and Temperatures

Prior to the onset of burbot sampling, a conditional agreement was formulated with Bonneville Power Administration (BPA) and U.S. Army Corps of Engineers (USACE) to provide three experimental minimum flows for burbot pre-spawn and spawning migrations. Our intention was to test the H<sub>0</sub> hypothesis that winter discharge for power production does not inhibit burbot migration to spawning tributaries. There were to be three minimum discharge (113 m<sup>3</sup>/s) periods from Libby Dam of five days duration during November and December 1996 and January 1997 (Figure 3). We hypothesized these minimum flow periods would replicate pre-dam winter flow conditions and induce burbot to move upstream. In turn, we expected that the return of unrestricted water management after each test would inhibit continued upstream movement or compel burbot to move downstream.

Daily discharge and temperature values for the Kootenai River were obtained from USACE and the U.S. Geological Survey (USGS) office in Sandpoint, Idaho. Stowaway XI temperature loggers were used to monitor daily water temperatures in Smith and Boundary Creeks, Idaho and in the Goat River, BC, from November 1, 1996 to March 31, 1997.

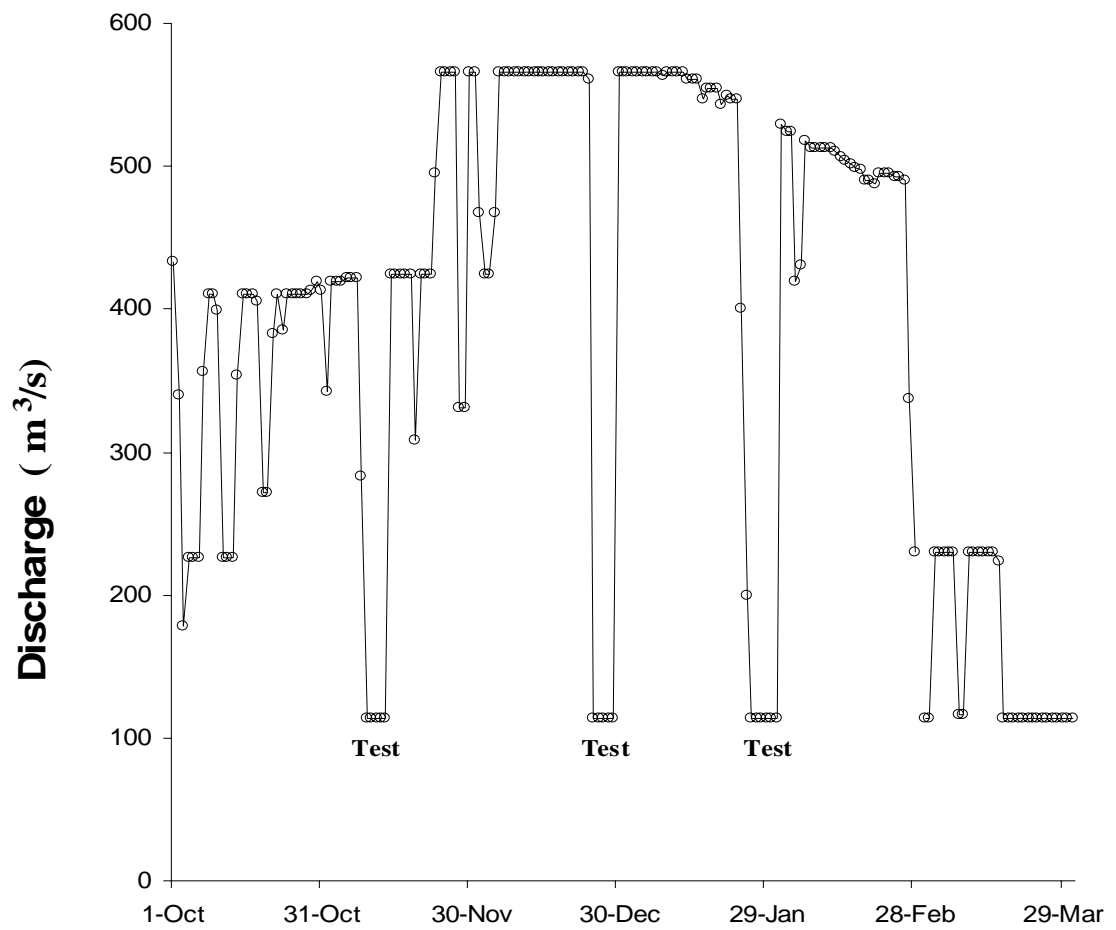


Figure 3. Proposed discharges in the Kootenai River to test the  $H_0$  hypothesis that burbot migrations are not inhibited during power production.

### **Hoop Net Sampling**

The 1996-1997 burbot sampling was a joint effort by IDFG and the British Columbia Ministry of Environment (BCMOE) fisheries staff. We partitioned the Kootenai River into two study segments, with a km of overlap, and we sampled independently. The BCMOE crew sampled for burbot from the Kootenay River mouth to about Nick's Island (rkm 119.0 to 144.9) and IDFG sampled burbot in the Kootenai River in Idaho and BC from a point downstream of Nick's Island, BC, to Ambush Rock in Idaho (rkm 143.9 to 244.8). Our expectation was interception of burbot moving from Kootenay Lake and the lower river to their historic spawning areas in Idaho and BC. Each team sampled for burbot with 3 to 11 hoop nets of two sizes from October 21, 1996 through March 24, 1997 (for a description of the nets and method of deploying them see Paragamian 1995).

Hoop nets were checked every 24 to 72 h. Captured fish were identified by species, enumerated, measured in total length (TL), and weighed to the nearest gram (g). Catch effort (C/E) was calculated as total fish or burbot catch/24 hour net day. All burbot were passive integrated transponder (PIT) tagged and a small piece of pelvic fin tissue was collected for genetic analysis. Relative Weights ( $W_r$ ) (Fisher 1997) were calculated and compared to data in the literature.

### **Egg and Larval Sampling**

We set 2 drift nets (mouth area =  $0.847 \text{ m}^2$ ) in the Goat River, BC from February 4 through March 13, 1997 in an effort to capture larval/young of the year (YOY) burbot and eggs drifting from spawning areas. Drift nets were secured in the lower half of the water column with anchors, ropes, and buoys. A Gurley 2030 R current meter was mounted in the mouth of each net. Nets were fished from 4 to 27 hours per set. Effort was calculated using total set time, current velocity, and the mouth area to estimate the total volume of water ( $\text{m}^3$ ) filtered through each net.

From March through August, three different netting methods were employed to capture YOY burbot (Paragamian et al. in progress). We towed two  $\frac{1}{2}$  m nets at the surface and at subsurface depths in the Kootenai River and Kootenay Lake. A shrimp trawl was used to sample the bottom of the Kootenai River and a midwater trawl was used by the Canadian team to sample Kootenay Lake.

### **Burbot Telemetry**

Sonic transmitters were surgically implanted in burbot captured in hoop nets. Sonic transmitters have 40, 60, 420, or 1800 d life expectancies (for a description of the surgical procedures see Paragamian 1995). Sonic transmitters were cylindrical in shape and ranged in size from 16 mm x 37 mm and 4 g (40 and 60 d) to 18 mm x 65 mm and 8 g (1800 d transmitter). Sex was recorded during surgery. Most burbot were released at the capture site; however, sonic 1/2 and 276 were transported upstream by boat 4.8 km and 1.0 km respectively, and released. The latter two fish were moved upstream to determine if they would return to their original location.

Burbot movement was monitored from September 1, 1996 through August 31, 1997, on a minimum of two days each week, occasionally on weekends, and commonly when hoopnets were checked. When burbot were located by telemetry the rkm was recorded, depth was measured with an echo sounder, and velocity was measured within 15 cm of the bottom (using a Marsh-McBirney 201A electronic current meter).

### **Genetic Analysis**

Tissue samples were collected from three separate locations within the Kootenai River Basin (Figure 1): (1) from rkm 145 to 245, (2) from below Libby Dam (at rkm 352) and (3) above Libby Dam by fisheries staff of the Montana Department of Fish Wildlife and Parks (MFWP). The samples represent three putative burbot stocks: 1) Kootenay Lake and Kootenai River below Kootenai Falls, 2) Kootenai River above Kootenai Falls and below Libby Dam, and 3) Lake Koocanusa formed by Libby Dam. Tissue samples from burbot were stored in 70% ethanol until DNA was extracted using methods from Sambrook et al. (1989) and Dowling et al. (1990). Mitochondrial DNA (mtDNA) analysis was conducted at the University of Idaho Aquaculture Research Institute in Moscow, Idaho, under the supervision of Dr. Matt Powell.

## **RESULTS**

### **Kootenai River Discharge and Temperatures**

The first test flow occurred in November when flows from Libby Dam were reduced from about 425 m<sup>3</sup>/s on November 7, 1996 to 113.3 m<sup>3</sup>/s by November 9, but it was only three days in duration (Figure 4). The test continued until November 11, flows were gradually ramped up to an average of 345 m<sup>3</sup>/s on November 12, 425 m<sup>3</sup>/s by November 13, and to 567 m<sup>3</sup>/s on November 20. The second test in December was also incomplete (three days) due to a demand for flood storage and the third in January was not provided.

Temperature of Boundary and Smith creeks ranged between 0 and 1<sup>0</sup> C during the spawning season (Figure 5). More temperature data for the Kootenai and Goat rivers is presented in the text of this report (Figure 6).

Discharge in the Kootenai River from Libby Dam remained high during most of the spawning period but after burbot completed spawning the USACE reduced flows (Figure 4). Discharge during the last week in February was reduced to base flow of about 113.3 m<sup>3</sup>/s, and remained low through March 17, 1997. Reduced discharge was the result of very low inflow into Lake Koocanusa and because the USACE reduced flows to store water.

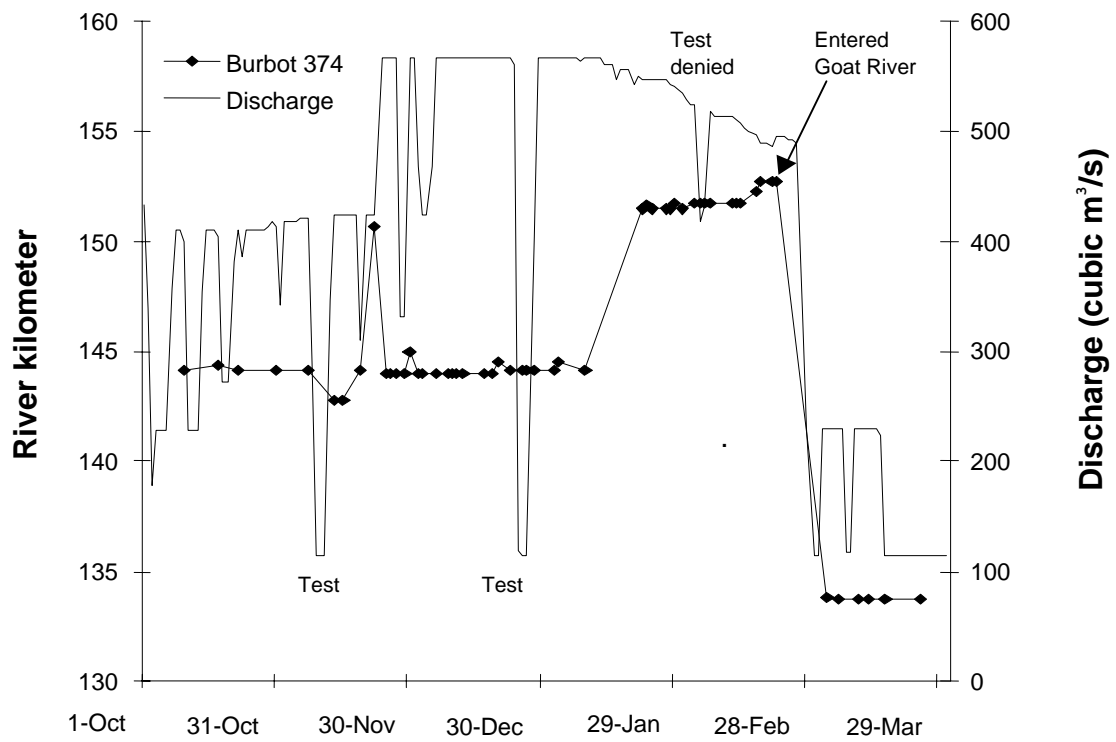


Figure 4. Kootenai River discharge from Libby Dam and movement of burbot 374 from October 1, 1996 through March 31, 1997.

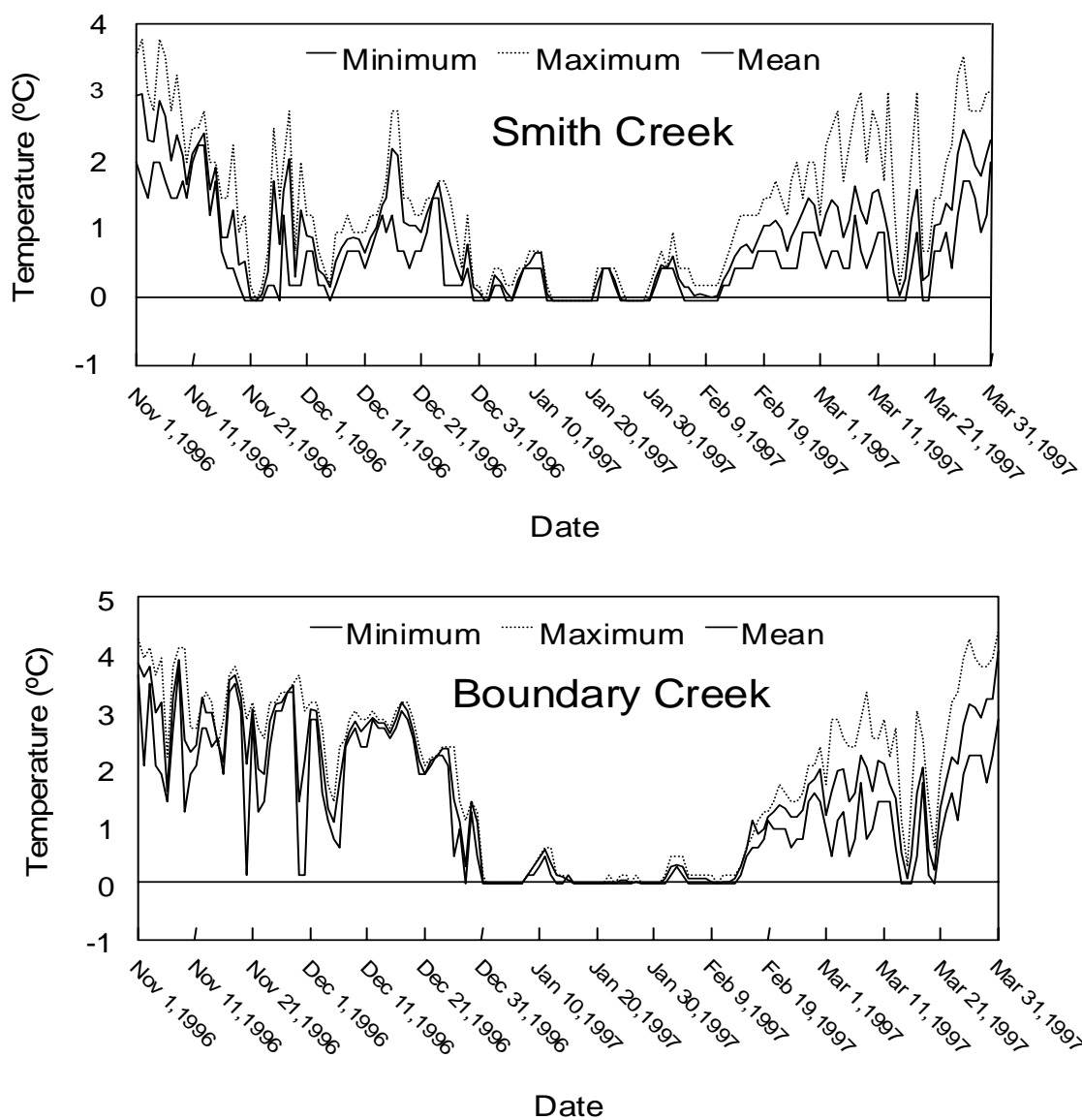


Figure 5. Temperature of two Kootenai River tributaries November 1996 through March 1997; top figure is Smith Creek and the lower figure is Boundary Creek.



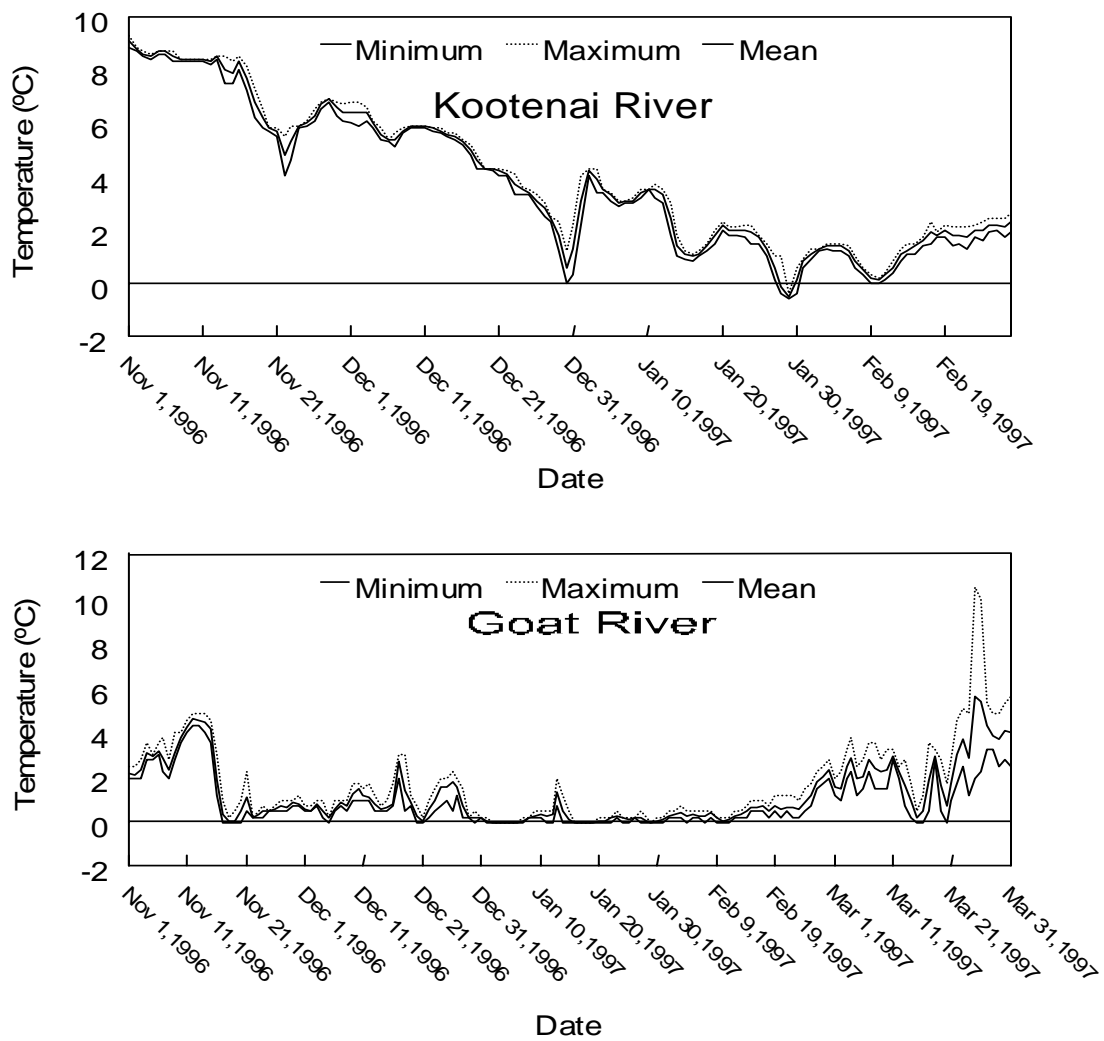


Figure 6. Temperature of the Kootenai River at Porthill, Idaho from November 1996 through February 1997 and Goat River, BC, Canada from November 1996 through March 1997.

## **Hoop Net Sampling**

### **Total Catch**

We fished baited hoop nets from October 21, 1996 through March 21, 1997 for a total of 1,048 net days. A total of 156 fish were caught of which 23 were burbot, 70 northern pikeminnow *Ptychocheilus oregonensis*, 25 black bullhead *Ameiurus melas*, nine peamouth *Mylocheilus caurinus*, six longnose *Catostomus catostomus* and largescale *C. macrocheilus* suckers, eight bull trout *Salvelinus confluentus*, seven rainbow trout *Oncorhynchus mykiss*, and two each brook trout *Salvelinus fontinalis* and pumpkinseed *Lepomis gibbosus* (Table 1). Yellow perch *Perca flavescens*, cutthroat trout *Oncorhynchus clarki*, redbreast shiner *Richardsonius balteatus*, and rainbow-cutthroat hybrid trout each accounted for a total of one each in the catch. Catch/unit of effort was 0.15 fish/net day and 0.02 burbot/net day (Table 1).

BCMOE fished baited hoop nets from November 8, 1996 to February 10, 1997 for a total of 844 net days. A total of 82 fish were caught of which one was a burbot, 33 black bullhead, 25 northern pikeminnow, 12 peamouth, eight cutthroat trout, two yellow perch, and one sucker longnose or largescale sucker (Appendix A). The total catch per unit of effort was 0.10 fish/net day and burbot was 0.001 fish/net day (Appendix A).

We captured a total of 23 burbot and BCMOE captured one (Table 1, Figure 7, and Appendix A). Only two burbot were caught in Idaho. Hoop nets captured one burbot at the mouth of Boundary Creek before the spawning season and one after but none at Smith Creek. The remaining 22 burbot were caught in BC (19 in the Kootenai River and three in the Goat River, at rkm 152). Three burbot caught in BC were recaptures from the previous spawning season. Burbot ranged from 450 to 743 mm total length (Figure 7) and weighed from 700 to 2,700 g (mean = 1,323 g). Relative weights ranged from 84 to 107% and averaged 95% (S.D.= 8.26).

### **Spawning Burbot in Net Catch**

Three adult burbot were captured February 10, 1997 in the Goat River on an apparent spawning run but no burbot were captured in Idaho during or after the spawning period.

Table 1. Hoop net catch success by number, weight (kg), and catch per unit effort (CPUE), Kootenai and Goat rivers, Idaho and BC, October, 1996 through March, 1997.

| Species                | Number | Total weight (kg) | CPUE <sup>a</sup> |
|------------------------|--------|-------------------|-------------------|
| Redside shiner         | 1      | .175              | .0010             |
| Yellow perch           | 1      | .300              | .0010             |
| Cutthroat trout        | 1      | .380              | .0010             |
| “Cut-bow” hybrid trout | 1      | .700              | .0010             |
| Pumpkinseed            | 2      | .100              | .0019             |
| Brook trout            | 2      | .525              | .0019             |
| Sucker <sup>b</sup>    | 6      | 1.875             | .0057             |
| Rainbow trout          | 7      | 1.072             | .0067             |
| Bull trout             | 8      | 5.311             | .0076             |
| Peamouth               | 9      | 1.416             | .0086             |
| Black bullhead         | 25     | 3.135             | .0239             |
| Northern pikeminnow    | 70     | 36.611            | .0668             |
| Burbot                 | 23     | 30.424            | .0219             |

<sup>a</sup>A unit of effort is a single 24-hour set.

<sup>b</sup>Includes longnose and large scale suckers.

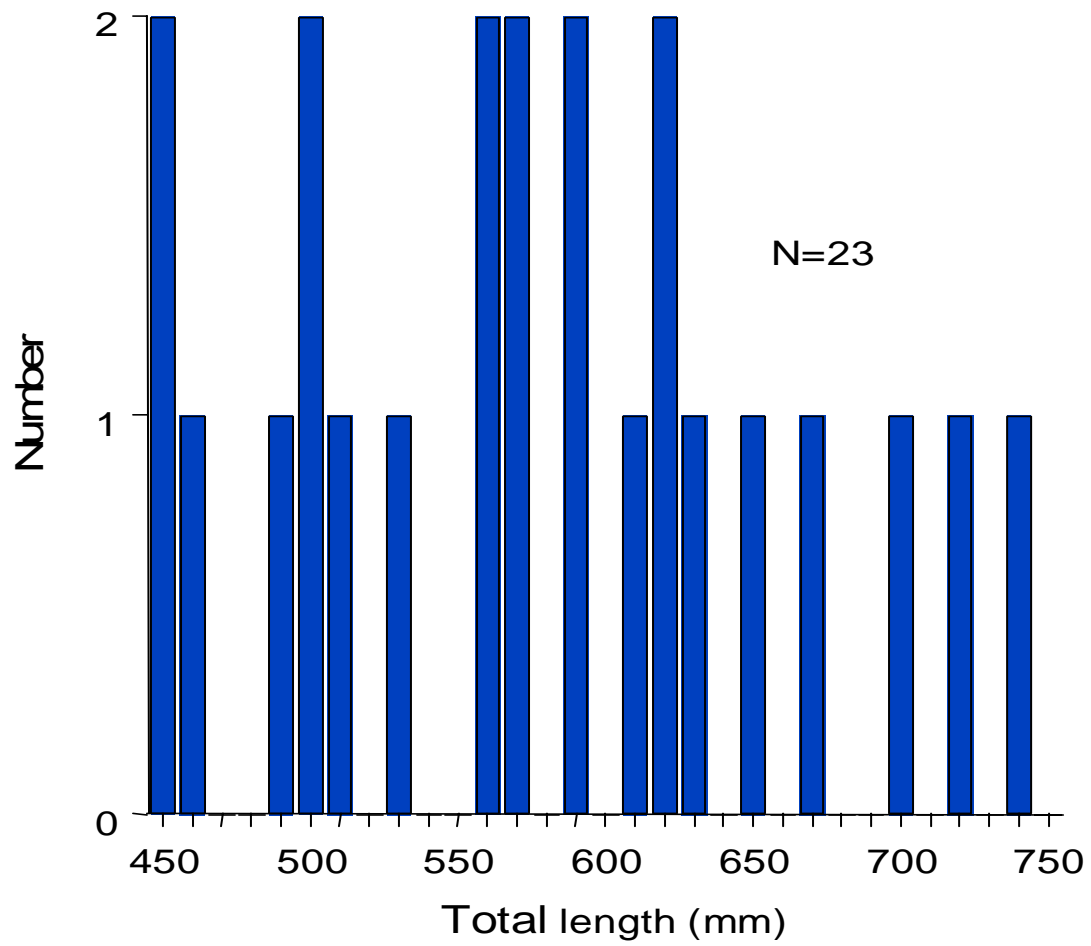


Figure 7. Length frequency distribution of burbot caught by baited hoop nets in the Kootenai and Goat rivers, November 1996 through March 1997.

## **Egg and Larval Sampling**

To document spawning in the Goat River we searched for burbot eggs with two drift nets from February 3 through March 13 and sampled 2,132 m<sup>3</sup> of water in 954 net hours. One egg of unknown species was captured but no larval burbot were seen. Meter net tows and shrimp trawl efforts are reported in a companion study (Paragamian et al. in progress); they failed to capture any larval or juvenile burbot. Midwater trawl effort also failed to capture burbot.

## **Burbot Telemetry**

### **Pre-spawn Period**

Two burbot previously implanted with transmitters were at large during the first pre-spawn minimum flow test, 374 and 357 (Table 2 and Appendices B and C). Both burbot were sedentary during the month of September. Burbot 374 progressively moved upstream from about rkm 133 to rkm 144 during October to a pool at Nick's Island, which was already occupied by 357 (rkm 144) (Figure 4). Water temperature during this migration was about 10°C (Figure 6). Both burbot remained at about rkm 144 until the first test flow. During the first test (three days), flows from Libby Dam were reduced from about 425 m<sup>3</sup>/s on November 7, 1996 to 113 m<sup>3</sup>/s by November 9 (Figure 4). The test continued until November 11, flows were gradually ramped up to an average of 345 m<sup>3</sup>/s on November 12, 425 m<sup>3</sup>/s by November 13, and to 567 m<sup>3</sup>/s on November 20. Burbot 374 did not respond immediately to the test but during the ramp up phase it moved from rkm 142.8 on November 15 to rkm 150.7 by November 22 (Appendix B and Figure 4). When flow exceeded 425 m<sup>3</sup>/s it returned to rkm 144. Burbot 357 could not be located during the flow test (Appendix L). There is about a day lag period in water travel time between the dam and the Nick's Island reach (rkm 144).

The second pre-spawn flow test started on December 25, 1996 and lasted three days (Figure 4); our goal was for five days. The test was shortened by the USACE because of flood control concerns. Nine burbot had sonic transmitters at the initiation of this test (Appendices B through H, L, and M). Six burbot were already in the immediate vicinity of the Goat River. There was very little movement upstream or downstream and the test did not result in any obvious burbot movement.

Burbot 374, 3334, and 96 were about eight or more km downstream from the Goat River (Appendices B, D, and H) during the second test. After the test these burbot began a slow migration upstream and joined the main body of spawners between rkm 149 and 151 during a discharge of 566.7 m<sup>3</sup>/s from Libby Dam. This trio of fish progressively moved upstream: 96 began November 29 while 374 and 3334 started in early January. We calculated minimum travel times for each burbot; taking burbot 3334 - 17 days to go 7.9 km (0.46 km/day), burbot 96 - 15 days to travel 8.7 km (0.58 km/day), and burbot 374 - 11 days to go 7.4 km (0.67 km/day).

Table 2. Summary of sonic telemetry data and physical characteristics of 11 burbot monitored in the Kootenai River, Idaho, and British Columbia, Canada 1996 through 1997.

| Sonic code | Date implanted | Total length (mm) | Weight (g) | PIT tag number | Sex | Last date located |
|------------|----------------|-------------------|------------|----------------|-----|-------------------|
| 374        | 02/20/96       | 590               | 1135       | 7F7DOB684C     | M   | 08/28/97          |
| 96         | 11/22/96       | 626               | 1450       | 7F7D430070     | M   | 08/28/97          |
| 383        | 11/22/96       | 568               | 1145       | 7F7D24071E     | M   | 04/15/97          |
| 2228       | 12/04/96       | 678               | 1890       | 7F7D29757B     | F   | 08/05/97          |
| 2237       | 12/04/96       | 570               | 1400       | 7F7DOA417E     | F   | 08/28/97          |
| 3334       | 12/17/96       | 618               | 1800       | 7F7D374E69     | F   | 08/28/97          |
| 2632       | 12/17/96       | 655               | 1710       | 7F7D424726     | F   | 08/28/97          |
| 93         | 12/17/96       | 494               | 755        | 7F7D42472F     | F   | 07/29/97          |
| 293        | 01/14/97       | 702               | 2550       | 7F7DOA246E     | F   | 07/07/97          |
| 12         | 01/19/97       | 595               | 1356       | 7F7D401C23     | M   | 08/19/97          |
| 276        | 1/19/97        | 570               | 1430       | 7F7D31682E     | M   | 05/28/97          |

## **Spawning Period**

Eleven burbot were monitored between February 1 and February 26, 1997 (Table 2 and Appendices B through L), a third test was not provided. Temperature of the Kootenai River ranged from 0 to 2.5°C (Figure 6). Telemetry indicated burbot had gradually moved upstream, during unrestricted operation of Libby Dam, to the mouth of the Goat River (Appendices B through M) where at least four burbot with transmitters moved up the Goat River during the spawning season. Temperature of the Goat River during the spawning period ranged from 0 to 2.5°C (Figure 6). Telemetry in the Goat River was restricted to approximately the lower 2 km due to shallow water, surface ice, and woody debris. Thus, they could not be monitored from a boat.

## **Post-spawn Period**

Ten burbot were monitored during the post-spawn period, which began in late February when burbot with transmitters left the Goat River (Table 2 and Appendices B through J). Burbot 374 returned to rkm 133.7 where it had been the previous summer and autumn of 1996. Concurrent to the cessation of burbot movement was a rise in river temperature and discharge from April through May 8, 1997. When river temperature reached 7°C most burbot became relatively sedentary and remained in deep pools (96, 383, 2228, 2237, 3334, 2632, 93, and 293). Discharge rapidly increased through May and June to over 1,600 m<sup>3</sup>/s. Burbot 12 eventually traveled to the confluence with Kootenay Lake delta and has not been relocated since.

## **Genetic Analysis**

Analysis of mtDNA variation among three gene regions, from burbot sampled from three locations in the Kootenai River, revealed 7 composite mtDNA haplotypes (henceforth haplotypes) labeled Bur-01 through Bur-07 (Table 3). Two of these haplotypes, Bur-01 and Bur-02, were observed common to all three burbot samples though the frequency of these haplotypes in each sample differed. The frequency of Bur-01 in burbot sampled above Kootenai Falls was significantly different ( $P < 0.05$ , Felsenstein 1993) than the downstream sample in the Kootenai River and Kootenay Lake. Bur-01 was observed as the predominant haplotype in the Kootenay Lake, BC/Kootenai River, Idaho sample (KT) with a frequency of 0.73. In contrast, the frequency of Bur-01 among the Kootenai River, Montana sample (MT) and Lake Koocanusa sample (LK) was 0.28 and 0.25, respectively. A simultaneous increase in Bur-02 frequency among the burbot sample above Kootenai Falls was also observed. The frequency of Bur-02 among the KT sample was 0.11. Comparatively, Bur-02 was observed as the predominant haplotype among the MT and LK burbot populations with frequencies of 0.56 and 0.80, respectively.

Haplotype diversity also differed among the sampled populations. The burbot population below Kootenai Falls, KT, exhibited five haplotypes, three of which Bur-03, Bur-04, and Bur-05 are not shared with the MT or LK populations and have a combined frequency of 0.19. Likewise, two additional haplotypes were observed only in the MT burbot population, Bur-06, and Bur-07 with a combined frequency of 0.17. The LK population exhibited the least haplotype diversity with only Bur-01 and Bur-02 observed. Percent sequence divergence among haplotypes was low within all populations. Values ranged from 0.007-0.043% in MT samples, were highest 0.020-0.052% in KT samples, and 0.021% in LK samples (Table 4).



Table 3. Composite mtDNA haplotypes observed among three burbot populations from the Kootenai River Basin (N=55) and the number of samples observed.

| Location                | N  | Simple Haplotypes | Composite |             |
|-------------------------|----|-------------------|-----------|-------------|
|                         |    |                   | Haplotype | Designation |
| Kootenay Lake, BC and   | 19 | AAAAAA            | Bur-01    |             |
| Kootenai River, Idaho   | 3  | AAAABA            |           | Bur-02      |
|                         | 1  | AAAADA            | Bur-03    |             |
|                         | 2  | AAAAEA            |           | Bur-04      |
|                         | 2  | ABAADA            | Bur-05    |             |
| Kootenai River, Montana | 5  | AAAAAA            |           | Bur-01      |
|                         | 10 | AAAABA            |           | Bur-02      |
|                         | 2  | AAABAA            | Bur-06    |             |
|                         | 1  | BAAAAA            | Bur-07    |             |
| Lake Koocanusa, Montana | 2  | AAAAAA            |           | Bur-01      |
|                         | 8  | AAAABA            |           | Bur-02      |

Table 4. Percent sequence divergence among seven mtDNA haplotypes observed in burbot populations from the Kootenai River Basin. Composite haplotype designations are from Table 3.

|        | Composite Haplotype |        |        |        |        |        |
|--------|---------------------|--------|--------|--------|--------|--------|
|        | Bur-01              | Bur-02 | Bur-03 | Bur-04 | Bur-05 | Bur-06 |
| Bur-02 | 0.0211              |        |        |        |        |        |
| Bur-03 | 0.0211              | 0.0278 |        |        |        |        |
| Bur-04 | 0.0224              | 0.0294 | 0.0294 |        |        |        |
| Bur-05 | 0.0430              | 0.0495 | 0.0200 | 0.0524 |        |        |
| Bur-06 | 0.0072              | 0.0294 | 0.0294 | 0.0313 | 0.0524 |        |
| Bur-07 | 0.0211              | 0.0430 | 0.0430 | 0.0456 | 0.0656 | 0.0294 |

## **DISCUSSION**

### **Burbot Population Status**

Burbot in Idaho are nearly demographically extinct. The lower Kootenai River and Kootenay Lake act as a reservoir for the few remaining fish but burbot numbers diminish rapidly upstream of the Goat River. We caught only five burbot from late November 1995 through March 1997 in Kootenai River, Idaho. Previous burbot studies have attested to their low densities in Idaho (Paragamian 1994 and 1995). This genetically distinct stock of fish may soon be beyond recovery. Our studies have determined important distributional, biological, genetic findings for the population, and several hypotheses limiting the population have been presented but a recovery plan has not been devised.

### **Burbot Flow Test**

Our hypothesis testing for the 1996 - 1997 spawning season for burbot was incomplete. The November and December tests were carried out but were only three days in length. Each was cut short. The January test was denied, as previously reported.

Our first flow test provided minimal insight into burbot response to reduced flows. Burbot 374 moved from rkm 143 to rkm 151 at the end of the test when flows were being ramped up, but gradually moved back downstream when flow from Libby Dam exceeded  $425 \text{ m}^3/\text{s}$ . The second fish could not be relocated; thus, this fish did not provide us with any definitive information.

Travel rate of burbot under various flow regimes may provide an alternative measure of burbot performance. Travel rates calculated for a small number of tagged fish indicated burbot may be two to three times slower during winter operations when flows from Libby Dam range from 425 to  $708 \text{ m}^3/\text{s}$ . For example, travel rate of burbot 374 was about 1.3 km/day at the end of the first low flow test. Several weeks later, 374 began a second upstream migration during much higher flows and it progressed at an estimated 0.67 km/day. Burbot 3334 and 96 (both tagged after the first flow test) traveled at a rate of 0.46 and 0.58 km/day (Appendices B, D, and H), respectively, during the same high flows (Figure 4). Several years earlier (1995) the senior author recorded the estimated travel rate of three burbot on an apparent spawning migration. The migration occurred late in the spawning season when the USACE dropped flows, these burbot traveled at 1.0, 1.34, and 1.14 km/day. One fish had started its migration at Crawford Bay of Kootenay Lake (Paragamian 1995) and spent several weeks in the vicinity of the Kootenai River delta, moving upstream only after flows at Libby Dam were reduced to  $113 \text{ m}^3/\text{s}$ . There is some error in all of these estimates, the most important of which is unknown, the actual amount of time a burbot is moving. Burbot were known to spawn in many tributary streams in Idaho including Boundary, Smith, Parker, and Deep creeks. These streams are up to 120 km from Kootenay Lake and with the extended travel time, due to slower migration, burbot could be losing spawning synchrony thought to be important (Becker 1983) as well as other physiological changes we cannot measure in our study.

## **Burbot Biology**

Some researchers (Martin 1976) have speculated that burbot may be alternate year spawners. Our recaptures of three burbot at the Goat River during the 1997 spawning run (tagged the previous spawning season) and the return of burbot 374 to the Goat River indicate at least a segment of the population are annual spawners. Recaptures of more burbot are needed to substantiate this supposition.

## **Genetics**

Brown (1983) indicated mitochondrial DNA generally evolves at a rate of approximately 2% per million years. Unfortunately, this rate which is rapid compared to nuclear gene regions, is still too slow to allow for much nucleotide divergence between populations that have become isolated only within the past 10,000 years. Even with complete isolation, populations that have colonized habitats since the Pleistocene will show little genetic divergence (Billington and Hebert 1991). Thus, it is unlikely burbot stocks above and below Kootenai Falls can be differentiated solely based upon nucleotide divergence in mtDNA that has arisen since their recent separation. However, mtDNA can be used for stock discrimination in other ways. First, divergence can still be observed between recently separated populations. It is important to realize that this divergence is most likely due to sampling effects associated with population founding (Billington and Hebert 1991). Secondly, shifts in mtDNA haplotype frequency are commonly used to discriminate stocks and have been used in a number of studies (Wilson et al. 1987; Bentzen et al. 1989; Mulligan et al. 1992).

The burbot population below Kootenai Falls (KT) exhibits two haplotypes (Bur-03 and Bur-05) that are most divergent from the other five haplotypes observed. These two haplotypes likely indicate mtDNA polymorphisms pre-dating isolation of the burbot population. Moreover, the absence of Kootenai River above the Kootenai Falls (MT) haplotypes Bur-06 and Bur-07 in the KT population below the Kootenai Falls also indicates a lack of immigration from upstream populations. Sampling from the BC/Idaho border (rkm 170) to the Idaho/Montana border (rkm 276) indicated burbot were nearly nonexistent (Paragamian 1993). The changes in predominant haplotype frequencies (Bur-01 and Bur-02) between the KT stock and the MT/LK (LK - Lake Koocanusa) stocks further supports the hypothesis that these populations form distinct stocks.

Different life history characteristics could be expected for the two burbot stocks because they are within different habitats and separated by a barrier. The mtDNA analysis supports tagging and telemetry studies that indicate burbot in BC/Idaho are the same stock (Paragamian 1995). In Idaho, burbot tagged with transmitters have moved no further upstream than rkm 246. Burbot also move freely between the river and lake and after a pre-spawning migration, spawn in tributaries to the river (Paragamian 1995). Studies in Montana have shown burbot in Lake Koocanusa are entrained through Libby Dam (Skarr et al. 1996). Also, telemetry of burbot in Lake Koocanusa suggests a spawning run through the unregulated river as far upstream as rkm 475 and burbot tagged with sonic transmitters in Montana have not moved downstream into Idaho (Scott Snelson, Montana Fish Wildlife and Parks, personal communication).

## **Genetic Preservation**

Creation of spawning refuges in Idaho tributaries by introducing pre-spawn burbot transported from the lower reaches of the Kootenai River, may be a viable method to enhance the burbot population. Pre-spawn burbot could be captured in the lower Kootenai River or Duncan Lake (providing they are of the same stock) and released into an enclosed reach (a weired section) of a tributary stream in Idaho. These burbot could be monitored in the enclosed reach and spawning verified by collection of fertilized eggs with drift nets. After spawning, the adults could be returned to capture locations or released on site. This task in effect would circumvent the migration ordeal burbot are confronted with each spawning season and possibly establish a fluvial population in Idaho. If high winter flows are a migration barrier to spawning adults the numbers of burbot in the lower river should improve within several generations and/or a spawning stock of burbot will be developed if mitigative flow measures become a reality. Further review is necessary before implementation of this concept.

## **RECOMMENDATIONS**

1. Test the  $H_0$  hypothesis that high winter discharge does not inhibit migration of burbot upstream to Idaho.
2. Determine the distance traveled by migrating burbot to estimate the necessary time needed for migrations to Boundary, Smith, and Parker creeks in Idaho.
3. Capture and examine post-spawn burbot in Idaho to determine whether or not they spawned.
4. Continue experimental capture techniques for larval burbot with midwater trawls, sleds, beam trawls, drop nets, meter nets, seine nets, etc.
5. Assess the potential for maintaining a captive breeding population of Kootenai River burbot in the basin. The objective would be to maintain a genetic resource until a recovery agreement can be forged with management agencies.

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## **APPENDICES**



Appendix A. Hoop net catch success by number, weight (kg), and catch per unit effort<sup>a</sup> (CPUE), Kootenai River, BC, November 1996 through February 1997. Catch by BCMOE.

| Species         | Number | Total weight (kg) | CPUE  |
|-----------------|--------|-------------------|-------|
| Yellow perch    | 2      | .14               | .0002 |
| Cutthroat trout | 8      | 5.63              | .0009 |
| Sucker          | 1      | .18               | .0001 |
| Peamouth        | 12     | 1.38              | .0100 |
| Black bullhead  | 33     | 1.92              | .0400 |
| Squawfish       | 25     | 17.67             | .0300 |
| Burbot          | 1      | 1.23              | .0001 |

<sup>a</sup>A unit of effort is a single 24-hour set.

Appendix B. Location (rkm), date, velocity, temperature, and depth of burbot 374 as determined by sonic telemetry, Marsh-McBirney current meter and Eagle depth sounder.

| Date                  | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|-----------------------|-------------------|--------------|--------------------|-------------------------|
| 02/20/96 <sup>a</sup> | 152.6             | 2.26         |                    |                         |
| 02/21/96              | 152.3             |              |                    | 5.0                     |
| 02/26/96              | 146.6             |              |                    | 3.5                     |
| 03/08/96              | 134.9             | 15.85        | 7.62               | 3.0                     |
| 03/15/96              | 133.6             | 25.21        | 13.87              | 6.0                     |
| 03/18/96              | 133.8             | 21.37        | 12.19              | 6.0                     |
| 03/20/96              | 133.7             |              |                    | 4.5                     |
| 03/28/96              | 133.8             | 27.43        | 9.14               | 4.0                     |
| 04/01/96              | 133.6             | 14.02        | 3.05               | 5.0                     |
| 04/05/96              | 137.2             | 18.29        | 21.34              | 7.0                     |
| 04/11/96              | 136.8             |              |                    | 7.0                     |
| 04/15/96              | 133.6             |              |                    | 7.0                     |
| 04/18/96              | 134.5             |              |                    | 7.0                     |
| 04/22/96              | 133.5             |              |                    | 6.0                     |
| 04/26/96              | 133.2             |              |                    | 5.0                     |
| 04/29/96              | 133.2             | 12.50        |                    | 6.0                     |
| 05/07/96              | 133.5             |              |                    | 7.0                     |
| 05/15/96              | 133.5             |              |                    |                         |
| 05/29/96              | 133.5             |              |                    | 10.0                    |
| 06/11/96              | 133.5             |              |                    |                         |
| 06/19/96              | 133.5             |              |                    |                         |
| 06/25/96              | 133.6             |              |                    |                         |
| 07/02/96              | 133.5             |              |                    |                         |
| 07/09/96              | 134.0             |              |                    |                         |
| 07/15/96              | 134.0             |              |                    |                         |
| 07/27/96              | 135.2             |              |                    | 18.0                    |
| 08/05/96              | 134.0             |              |                    |                         |
| 08/14/96              | 133.8             | 18.29        | 3.05               |                         |
| 08/20/96              | 134.1             |              |                    |                         |
| 09/05/96              | 133.7             |              | 3.05               |                         |
| 09/16/96              | 133.8             |              |                    | 14.5                    |
| 10/10/96              | 144.1             |              |                    |                         |
| 10/18/96              | 144.4             |              |                    | 10.0                    |
| 10/22/96              | 144.1             | 28.96        | 4.57               | 9.0                     |
| 10/31/96              | 144.1             | 18.29        | 15.24              | 9.0                     |
| 11/07/96              | 144.1             | 26.52        | 18.29              | 7.5                     |
| 11/13/96              | 142.8             | 16.76        |                    |                         |
| 11/15/96              | 142.8             | 27.43        | 6.10               |                         |
| 11/19/96              | 144.1             | 24.38        | 9.14               |                         |
| 11/22/96              | 150.7             | 22.86        | 15.24              |                         |
| 11/25/96              | 144.0             |              |                    | 5.0                     |
| 11/26/96              | 144.0             |              |                    | 6.0                     |
| 11/27/96              | 144.0             |              |                    |                         |
| 11/29/96              | 144.0             |              |                    | 6.0                     |
| 11/30/96              | 145.0             | 25.54        | 10.67              | 4.5                     |

Appendix B continued.

| Date | Location | Depth | Velocity | Water |
|------|----------|-------|----------|-------|
|------|----------|-------|----------|-------|

|                       | (rkm) | (m)   | (cm/s) | temperature °C |
|-----------------------|-------|-------|--------|----------------|
| 12/02/96              | 144.0 | 21.34 | 12.19  | 5.5            |
| 12/03/96              | 144.0 | 28.96 |        | 6.0            |
| 12/06/96              | 144.0 |       |        | 5.5            |
| 12/09/96              | 144.0 |       |        |                |
| 12/10/96              | 144.0 | 18.59 | 27.43  | 5.0            |
| 12/11/96              | 144.0 |       |        |                |
| 12/12/96              | 144.0 | 29.87 | 18.29  | 5.5            |
| 12/17/96              | 144.0 |       |        |                |
| 12/19/96              | 144.0 | 27.74 | 15.24  | 3.8            |
| 12/20/96              | 144.5 |       |        |                |
| 12/23/96              | 144.1 | 29.87 | 21.34  | 3.5            |
| 12/26/96              | 144.1 | 26.52 | 6.10   | 2.5            |
| 12/27/96              | 144.1 |       |        | 2.0            |
| 12/28/96              | 144.1 | 31.70 | 9.14   | 1.5            |
| 01/02/96              | 144.1 | 28.04 | 35.05  | 3.5            |
| 01/03/96              | 144.5 |       |        |                |
| 01/09/97              | 144.1 | 21.34 | 15.24  |                |
| 01/22/97              | 151.5 |       |        |                |
| 01/23/97              | 151.6 | 14.02 | 24.38  | 2.0            |
| 01/24/97              | 151.5 |       |        |                |
| 01/27/97              | 151.5 |       |        | 0.5            |
| 01/28/97              | 151.5 | 14.02 | 33.53  | 0.0            |
| 01/29/97              | 151.7 |       |        | -0.8           |
| 01/31/97              | 151.5 | 10.67 |        | 1.0            |
| 02/03/97              | 151.7 |       |        |                |
| 02/04/97              | 151.7 | 11.58 | 24.38  | 1.0            |
| 02/05/97              | 151.7 |       |        | 1.0            |
| 02/06/97              | 151.7 |       |        | 1.4            |
| 02/11/97              | 151.7 |       |        | 0.0            |
| 02/12/97              | 151.7 |       |        |                |
| 02/13/97              | 151.7 | 13.72 |        | 1.6            |
| 02/17/97              | 152.3 | 7.62  |        | 2.0            |
| 02/18/97              | 152.7 | 14.63 | 27.43  | 2.5            |
| 02/20/97 <sup>b</sup> | 152.7 |       |        |                |
| 02/21/97              | 152.7 | 10.97 |        | 1.1            |
| 03/04/97              | 133.8 | 32.00 |        | 2.5            |
| 03/06/97              | 133.7 | 21.34 |        | 1.9            |
| 03/11/97              | 133.7 | 27.43 |        | 3.2            |
| 03/13/97              | 133.7 |       |        | 2.2            |
| 03/17/97              | 133.7 | 31.70 |        | 1.5            |
| 03/25/97              | 133.7 |       |        | 3.0            |
| 04/03/97              | 133.7 |       |        |                |
| 04/09/97              | 133.5 |       |        |                |

Appendix B continued

| Date     | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|----------|-------------------|--------------|--------------------|-------------------------|
| 04/15/97 | 133.7             |              |                    | 6.5                     |
| 04/25/97 | 133.6             |              |                    | 6.0                     |
| 04/30/97 | 148.0             |              |                    | 6.5                     |
| 05/07/97 | 133.2             |              |                    | 8.0                     |
| 05/28/97 | 133.0             |              |                    | 8.5                     |
| 06/04/97 | 133.0             |              |                    | 8.5                     |
| 06/11/97 | 133.5             |              |                    | 10.5                    |
| 06/18/97 | 133.0             |              |                    | 12.0                    |
| 06/25/97 | 134.5             |              |                    | 11.0                    |
| 07/01/97 | 133.7             |              |                    |                         |
| 07/07/97 | 138.5             |              |                    | 14.0                    |
| 07/14/97 | 133.7             |              |                    | 13.5                    |
| 07/22/97 | 134.0             |              |                    | 18.0                    |
| 07/25/97 | 133.7             |              |                    | 18.0                    |
| 07/29/97 | 134.0             |              |                    |                         |
| 08/05/97 | 134.0             |              |                    | 19.5                    |
| 08/19/97 | 133.5             |              |                    |                         |
| 08/28/97 | 133.6             |              |                    |                         |

<sup>a</sup>Captured in Goat River, implanted and released. p 32

<sup>b</sup>Located approximately 0.7 km up the Goat River. p 33

Appendix C. Location (rkm), date, velocity, temperature and depth of burbot 357 as determined by sonic telemetry, Marsh-McBirney current meter and Eagle depth sounder.

| Date                  | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>Temperature °C |
|-----------------------|-------------------|--------------|--------------------|-------------------------|
| 02/13/96 <sup>a</sup> | 152.6             |              |                    |                         |
| 02/16/96              | 152.0             |              |                    | 2.0                     |
| 02/21/96              | 152.8             |              |                    | 5.0                     |
| 02/26/96              | 152.0             |              |                    | 3.5                     |
| 03/04/96              | 149.8             | 16.46        | 3.05               | 3.0                     |
| 03/08/96              | 144.0             | 16.76        | 15.24              | 3.0                     |
| 03/15/96              | 144.0             | 15.36        | 12.19              | 6.0                     |
| 03/18/96              | 143.5             | 12.80        | 28.96              | 6.0                     |
| 03/20/96              | 143.6             |              |                    | 4.5                     |
| 03/28/96              | 143.5             | 6.10         | 21.34              | 4.0                     |
| 04/01/96              | 144.4             | 21.34        | 18.29              | 5.0                     |
| 04/05/96              | 144.2             | 16.76        | 21.34              | 7.0                     |
| 04/11/96              | 143.8             | 7.62         | 39.62              | 7.0                     |
| 04/15/96              | 143.8             | 21.34        | 36.58              | 7.0                     |
| 04/18/96              | 143.9             |              |                    | 7.0                     |
| 04/22/96              | 143.9             |              |                    | 6.0                     |
| 04/26/96              | 144.0             |              |                    | 5.0                     |
| 04/29/96              | 144.7             | 14.63        |                    | 6.0                     |
| 05/07/96              | 144.0             |              |                    |                         |
| 05/15/96              | 144.5             |              |                    |                         |
| 06/11/96              | 144.2             |              |                    |                         |
| 06/19/96              | 144.2             |              |                    |                         |
| 07/02/96              | 144.0             |              |                    |                         |
| 07/09/96              | 144.2             |              |                    |                         |
| 07/15/96              | 144.2             |              |                    |                         |
| 07/27/96              | 144.4             |              |                    | 18.0                    |
| 08/05/96              | 144.2             |              |                    |                         |
| 08/14/96              | 143.8             | 8.23         | 1.52               |                         |
| 08/20/96              | 144.0             |              |                    |                         |
| 09/05/96              | 144.0             |              | 3.05               |                         |
| 09/16/96              | 144.1             |              |                    | 14.5                    |
| 10/10/96              | 143.8             |              |                    | 13.0                    |
| 10/18/96              | 144.3             |              | 0.00               | 10.0                    |
| 10/22/96              | 143.9             | 15.24        | 7.62               | 9.0                     |
| 10/31/96              | 144.0             | 19.20        | 15.24              | 9.0                     |
| 11/07/96              | 144.0             | 20.12        | 21.34              | 7.5                     |
| 11/13/96              | 144.1             | 18.29        | 24.38              |                         |
| 11/15/96              | 144.0             | 19.81        | 5.49               |                         |
| 11/19/96              | 144.1             | 24.38        | 9.14               |                         |

<sup>a</sup>Date of capture, implant and release.

Appendix D. Location (rkm), date, velocity, temperature and depth of burbot 96 as determined by sonic telemetry, Marsh-McBirney current meter and Eagle depth sounder.

| Date                  | Location (rkm) | Depth (m) | Velocity (cm/s) | Water Temperature °C |
|-----------------------|----------------|-----------|-----------------|----------------------|
| 11/20/96 <sup>a</sup> | 144.0          | 29.26     |                 |                      |
| 11/22/96 <sup>b</sup> | 144.0          |           |                 |                      |
| 11/25/96              | 144.0          |           |                 | 5.0                  |
| 11/26/96              | 144.0          |           |                 | 6.0                  |
| 11/27/96              | 144.0          |           |                 |                      |
| 11/29/96              | 145.2          |           |                 | 6.0                  |
| 11/30/96              | 146.1          | 7.41      | 13.72           | 4.5                  |
| 12/02/96              | 148.5          |           |                 | 5.5                  |
| 12/03/96              | 147.5          | 9.75      |                 | 6.0                  |
| 12/06/96              | 150.0          |           |                 |                      |
| 12/09/96              | 151.5          |           |                 |                      |
| 12/10/96              | 151.7          | 10.67     | 33.53           | 5.0                  |
| 12/11/96              | 152.5          |           |                 |                      |
| 12/12/96              | 152.5          | 9.45      | 45.72           | 5.5                  |
| 12/17/96              | 152.3          |           |                 |                      |
| 12/19/96              | 152.7          | 10.97     | 36.58           | 3.8                  |
| 12/23/96              | 152.7          | 15.88     | 19.81           | 3.5                  |
| 12/26/96              | 152.7          | 12.50     | 9.14            | 2.5                  |
| 12/27/96              | 152.7          |           |                 | 2.0                  |
| 12/28/96              | 152.7          | 17.01     |                 | 1.5                  |
| 01/02/97              | 152.0          | 12.50     | 24.38           | 3.5                  |
| 01/09/97              | 151.9          | 5.18      | 27.43           |                      |
| 01/10/97              | 152.0          |           |                 | 3.5                  |
| 01/15/97              | 152.1          | 6.71      | 25.9            |                      |
| 01/17/97              | 152.0          |           |                 | 0.5                  |
| 01/22/97              | 151.3          |           |                 |                      |
| 01/23/97              | 151.2          | 7.32      | 33.53           | 2.0                  |
| 01/24/97              | 151.2          |           |                 |                      |
| 01/27/97              | 151.3          |           |                 | 0.5                  |
| 01/28/97              | 151.3          | 3.05      | 16.76           | 0.0                  |
| 01/29/97              | 151.1          |           |                 | -0.8                 |
| 01/31/97              | 150.6          |           | 20.42           | 1.0                  |
| 02/04/97              | 150.7          | 2.44      | 1.52            | 1.0                  |
| 02/05/97              | 150.6          | 17.07     |                 | 1.0                  |
| 02/06/97              | 150.6          | 0.61      |                 | 1.4                  |
| 02/11/97              | 150.6          |           |                 | 0.0                  |
| 02/13/97              | 150.4          | 10.67     |                 | 1.6                  |
| 02/14/97              | 150.4          |           |                 | 1.6                  |
| 02/17/97              | 150.3          | 12.19     |                 | 2.0                  |
| 02/18/97              | 149.9          | 12.19     | 15.24           | 2.5                  |
| 02/20/97              | 150.4          |           |                 |                      |
| 02/27/97              | 150.5          | 12.80     | 24.38           | 3.0                  |

Appendix D continued.

| Date     | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|----------|-------------------|--------------|--------------------|-------------------------|
| 03/03/97 | 150.3             |              |                    | 2.5                     |
| 03/04/97 | 150.4             | 11.89        | 12.19              | 2.5                     |
| 03/11/97 | 150.4             | 15.24        |                    | 3.2                     |
| 03/13/97 | 150.4             |              | 15.24              | 2.2                     |
| 03/17/97 | 150.4             | 19.20        |                    | 1.5                     |
| 03/25/97 | 150.4             |              |                    | 3.0                     |
| 04/25/97 | 150.3             |              |                    | 6.0                     |
| 07/22/97 | 149.5             |              |                    | 18.0                    |
| 07/29/97 | 149.5             |              |                    |                         |
| 08/05/97 | 149.0             |              |                    | 19.5                    |
| 08/19/97 | 149.5             |              |                    |                         |
| 08/28/97 | 150.3             |              |                    |                         |

<sup>a</sup>Date of capture. p 36

<sup>b</sup>Implant and release date. p 36

Appendix E. Location (rkm), date, velocity, temperature and depth of burbot 383 as determined by sonic telemetry, Marsh-McBirney current meter and Eagle depth sounder.

| Date                  | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|-----------------------|-------------------|--------------|--------------------|-------------------------|
| 11/20/96 <sup>a</sup> | 170.0             |              |                    | 2.5                     |
| 11/22/96 <sup>b</sup> | 170.0             |              |                    |                         |
| 11/25/96              | 169.8             |              | 60.96              | 2.5                     |
| 11/26/96              | 169.5             |              |                    | 1.9                     |
| 11/27/96              | 169.0             |              |                    |                         |
| 11/29/96              | 169.0             |              |                    | 6.0                     |
| 11/30/96              | 168.9             | 16.09        | 9.14               | 4.5                     |
| 12/02/96              | 168.0             | 14.02        | 67.06              | 5.5                     |
| 12/03/96              | 167.0             | 20.73        |                    | 6.0                     |
| 12/06/96              | 165.0             |              |                    |                         |
| 12/09/96              | 163.0             |              |                    |                         |
| 12/10/96              | 162.0             | 11.58        | 18.29              | 5.0                     |
| 12/11/96              | 162.0             |              |                    |                         |
| 12/12/96              | 162.0             | 13.11        | 12.19              | 5.5                     |
| 12/17/96              | 161.8             |              |                    |                         |
| 12/19/96              | 160.2             | 17.07        | 39.62              | 3.8                     |
| 12/23/96              | 160.0             | 18.53        | 15.24              | 3.5                     |
| 12/26/96              | 159.7             | 14.33        | 4.57               | 2.5                     |
| 12/27/96              | 159.7             |              |                    | 2.0                     |
| 12/28/96              | 159.3             | 9.51         | 0.00               | 1.5                     |
| 01/02/97              | 157.5             | 7.62         | 15.24              | 3.5                     |
| 01/09/97              | 157.6             | 10.67        | 12.19              |                         |
| 01/10/97              | 157.6             |              |                    | 3.5                     |
| 01/15/97              | 157.6             | 12.80        | 33.53              |                         |
| 01/19/97              | 157.8             |              |                    | 2.0                     |
| 01/22/97              | 157.8             |              |                    |                         |
| 01/24/97              | 157.8             |              |                    |                         |
| 01/27/97              | 157.8             |              |                    | 0.5                     |
| 01/28/97              | 157.8             | 10.67        | 15.24              | 0.0                     |
| 01/29/97              | 157.8             |              |                    | -0.8                    |
| 01/31/97              | 157.5             | 12.19        |                    | 1.0                     |
| 02/03/97              | 157.7             |              |                    |                         |
| 02/04/97              | 157.7             | 10.67        | 9.14               | 1.0                     |
| 02/05/97              | 157.6             |              |                    | 1.0                     |
| 02/06/97              | 157.7             |              |                    | 1.4                     |
| 02/11/97              | 157.5             |              |                    | 0.0                     |
| 02/12/97              | 157.5             |              |                    |                         |
| 02/14/97              | 157.7             |              |                    | 1.6                     |
| 02/18/97              | 157.7             | 12.19        | 21.34              | 2.5                     |
| 02/20/97              | 157.9             |              |                    |                         |
| 02/21/97              | 157.9             |              |                    | 1.1                     |
| 02/27/97              | 157.9             | 13.11        | 19.81              | 3.0                     |
| 03/03/97              | 157.7             |              |                    | 2.5                     |
| 03/05/97              | 157.7             |              |                    | 1.9                     |



Appendix E continued

| Date     | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|----------|-------------------|--------------|--------------------|-------------------------|
| 03/11/97 | 157.7             | 7.62         |                    | 3.2                     |
| 03/14/97 | 157.5             |              |                    | 1.0                     |
| 03/17/97 | 157.5             | 9.75         | 28.96              | 1.5                     |
| 03/25/97 | 157.6             |              |                    | 3.0                     |
| 04/03/97 | 157.6             |              |                    |                         |
| 04/15/97 | 157.5             |              |                    | 6.5                     |

<sup>A</sup>Date of capture. p 38

<sup>b</sup>Implant and release date. p 38

Appendix F. Location (rkm), date, velocity, temperature and depth of burbot 2228 as determined by sonic telemetry, Marsh-McBirney current meter and Eagle depth sounder.

| Date                  | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|-----------------------|-------------------|--------------|--------------------|-------------------------|
| 12/02/96 <sup>a</sup> | 151.0             | 21.34        |                    | 5.5                     |
| 12/04/96 <sup>b</sup> | 151.0             |              |                    |                         |
| 12/06/96              | 150.7             |              |                    |                         |
| 12/09/96              | 150.5             |              |                    |                         |
| 12/10/96              | 150.5             | 24.69        | 30.48              | 5.0                     |
| 12/11/96              | 151.0             |              |                    |                         |
| 12/12/96              | 150.6             | 23.77        | 24.38              | 5.5                     |
| 12/17/96              | 150.6             |              |                    |                         |
| 12/19/96              | 150.5             | 22.25        | 15.24              | 3.8                     |
| 12/23/96              | 150.7             | 21.92        | 36.58              | 3.5                     |
| 12/26/96              | 150.6             | 20.73        | 1.52               | 2.5                     |
| 12/27/96              | 150.6             |              |                    | 2.0                     |
| 12/28/96              | 150.7             | 24.96        |                    | 1.5                     |
| 01/02/97              | 150.5             | 9.14         | 30.48              | 3.5                     |
| 01/09/97              | 151.7             | 6.40         | 24.38              |                         |
| 01/10/97              | 151.9             |              |                    | 3.5                     |
| 01/15/97              | 152.1             | 10.67        | 33.53              |                         |
| 01/17/97              | 151.6             |              |                    | 0.5                     |
| 01/22/97              | 150.3             |              |                    |                         |
| 01/23/97              | 150.3             | 8.53         | 27.43              | 2.0                     |
| 01/28/97              | 149.6             | 6.10         | 27.43              | 0.0                     |
| 01/29/97              | 149.6             |              |                    | -0.8                    |
| 02/03/97              | 148.3             |              |                    |                         |
| 02/04/97              | 148.3             | 9.45         | 27.43              | 1.0                     |
| 02/05/97              | 148.5             |              |                    | 1.0                     |
| 02/06/97              | 148.4             | 9.45         |                    | 1.4                     |
| 02/11/97              | 144.5             |              |                    | 0.0                     |
| 02/13/97              | 146.5             | 10.06        |                    | 1.6                     |
| 02/14/97              | 148.0             |              |                    | 1.6                     |
| 02/17/97              | 149.7             | 16.76        |                    | 2.0                     |
| 02/18/97              | 149.5             | 10.67        | 21.34              | 2.5                     |
| 02/20/97              | 152.5             |              |                    |                         |
| 02/21/97              | 152.5             | 8.84         |                    | 1.1                     |
| 02/24/97              | 152.7             | 12.19        |                    | 3.0                     |
| 04/03/97              | 150.8             |              |                    |                         |
| 04/24/97              | 147.0             |              |                    | 6.0                     |
| 04/30/97              | 147.5             |              |                    | 6.5                     |
| 05/07/97              | 147.0             |              |                    | 8.0                     |
| 05/14/97              | 147.5             |              |                    | 7.7                     |
| 05/21/97              | 147.0             |              |                    | 8.0                     |
| 05/28/97              | 147.0             |              |                    | 8.5                     |
| 06/04/97              | 147.0             |              |                    | 8.5                     |
| 06/11/97              | 148.0             |              |                    | 10.5                    |
| 06/18/97              | 147.5             |              |                    | 12.0                    |

Appendix F continued.

| Date     | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|----------|-------------------|--------------|--------------------|-------------------------|
| 06/25/97 | 147.1             |              |                    | 11.0                    |
| 07/01/97 | 147.1             |              |                    | 12.5                    |
| 07/07/97 | 147.2             |              |                    | 14.0                    |
| 07/14/97 | 147.5             |              |                    | 13.5                    |
| 07/22/97 | 148.0             |              |                    | 18.0                    |
| 07/25/97 | 147.0             |              |                    |                         |
| 07/29/97 | 147.0             |              |                    |                         |

<sup>a</sup>Date of capture. p 40

<sup>b</sup>Implant and release date. p 40

Appendix G. Location (rkm), date, velocity, temperature and depth of burbot 2237 as determined by sonic telemetry, Marsh-McBirney current meter and Eagle depth sounder.

| Date                  | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|-----------------------|-------------------|--------------|--------------------|-------------------------|
| 12/02/96 <sup>a</sup> | 151.0             | 21.34        |                    |                         |
| 12/04/96 <sup>b</sup> | 151.0             |              |                    |                         |
| 12/06/96              | 150.7             |              |                    |                         |
| 12/09/96              | 152.2             |              |                    |                         |
| 12/10/96              | 152.0             | 10.97        | 45.72              | 5.0                     |
| 12/11/96              | 152.2             |              |                    |                         |
| 12/12/96              | 152.1             | 13.41        | 18.29              | 5.5                     |
| 12/19/96              | 152.3             | 12.19        | 19.81              | 3.8                     |
| 12/23/96              | 152.0             | 20.97        | 13.71              | 3.5                     |
| 12/26/96              | 152.1             | 19.51        | 4.57               |                         |
| 12/27/96              | 152.1             |              |                    | 3.5                     |
| 12/28/96              | 152.2             | 23.26        | 5.79               |                         |
| 01/02/97              | 152.0             | 15.54        | 21.34              | 0.5                     |
| 01/09/97              | 151.4             | 6.25         | 35.05              |                         |
| 01/10/97              | 151.8             |              |                    | 2.0                     |
| 01/15/97              | 152.1             | 10.67        | 33.53              |                         |
| 01/17/97              | 152.4             |              |                    | 0.5                     |
| 01/22/97              | 152.3             |              |                    |                         |
| 01/23/97              | 152.2             | 15.24        | 21.34              | 2.0                     |
| 01/24/97              | 152.0             |              |                    |                         |
| 01/27/97              | 152.0             |              |                    | 0.5                     |
| 01/28/97              | 152.0             | 21.03        | 19.81              | 0.0                     |
| 01/29/97              | 152.0             |              |                    | -0.8                    |
| 01/31/97              | 152.0             | 11.58        |                    | 1.0                     |
| 02/03/97              | 152.0             |              |                    |                         |
| 02/04/97              | 152.0             | 15.85        | 24.38              | 1.0                     |
| 02/05/97              | 152.2             |              |                    | 1.0                     |
| 02/06/97              | 152.2             |              |                    | 1.4                     |
| 02/11/97              | 152.2             |              |                    | 0.0                     |
| 02/12/97              | 152.2             |              |                    |                         |
| 02/13/97              | 152.2             |              |                    | 1.6                     |
| 02/14/97              | 152.0             |              |                    | 1.6                     |
| 02/17/97              | 152.7             | 12.19        |                    | 2.0                     |
| 02/18/97              | 152.7             | 14.63        | 27.43              | 2.5                     |
| 02/20/97              | 152.8             |              |                    |                         |
| 02/24/97              | 152.7             | 3.66         |                    | 3.0                     |
| 02/25/97              | 152.7             |              |                    |                         |
| 02/27/97              | 152.2             | 16.76        | 45.72              |                         |
| 03/03/97              | 151.8             |              |                    | 2.5                     |
| 03/04/97              | 151.4             | 5.18         | 15.24              | 2.5                     |
| 03/05/97              | 150.6             |              |                    | 1.9                     |
| 03/06/97              | 150.6             | 24.38        |                    |                         |
| 03/10/97              | 150.4             |              |                    | 3.0                     |

Appendix G continued.

| Date     | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|----------|-------------------|--------------|--------------------|-------------------------|
| 03/11/97 | 150.2             | 7.62         |                    | 3.2                     |
| 03/13/97 | 150.2             |              |                    | 2.2                     |
| 03/25/97 | 149.7             |              |                    | 3.0                     |
| 04/03/97 | 152.2             |              |                    |                         |
| 04/09/97 | 151.6             |              |                    |                         |
| 04/15/97 | 151.4             |              |                    | 6.5                     |
| 04/30/97 | 148.0             |              |                    | 6.5                     |
| 05/07/97 | 148.0             |              |                    | 8.0                     |
| 05/14/97 | 144.5             |              |                    | 7.7                     |
| 05/21/97 | 140.8             |              |                    | 8.0                     |
| 06/04/97 | 146.0             |              |                    | 8.5                     |
| 06/18/97 | 146.3             |              |                    | 12.0                    |
| 06/25/97 | 148.2             |              |                    | 11.0                    |
| 07/07/97 | 146.2             |              |                    | 14.0                    |
| 07/14/97 | 146.2             |              |                    | 13.5                    |
| 07/22/97 | 147.0             |              |                    | 18.0                    |
| 07/25/97 | 146.2             |              |                    |                         |
| 07/29/97 | 146.5             |              |                    |                         |
| 08/05/97 | 146.5             |              |                    | 19.5                    |
| 08/19/97 | 146.0             |              |                    |                         |
| 08/28/97 | 146.5             |              |                    |                         |

<sup>a</sup>Date of capture. p 42

<sup>b</sup>Implant and release date. p 42

Appendix H. Location (rkm), date, velocity, temperature and depth of burbot 3334 as determined by sonic telemetry, Marsh-McBirney current meter and Eagle depth sounder.

| Date                  | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|-----------------------|-------------------|--------------|--------------------|-------------------------|
| 12/11/96 <sup>a</sup> | 144.4             | 16.76        |                    |                         |
| 12/17/96 <sup>b</sup> | 144.4             |              |                    |                         |
| 12/19/96              | 144.0             | 27.74        | 15.24              | 3.8                     |
| 12/23/96              | 144.1             | 29.87        | 21.34              | 3.5                     |
| 12/26/96              | 144.0             | 11.89        | 2.74               | 2.5                     |
| 12/27/96              | 142.9             |              |                    | 2.0                     |
| 12/28/96              | 143.0             | 17.86        | 3.05               | 1.5                     |
| 01/02/97              | 142.7             | 27.43        | 34.05              | 3.5                     |
| 01/09/97              | 142.7             | 24.38        | 21.34              |                         |
| 01/15/97              | 145.5             | 10.36        | 24.38              |                         |
| 01/19/97              | 146.6             |              |                    | 2.0                     |
| 01/22/97              | 147.4             |              |                    |                         |
| 01/23/97              | 147.5             | 10.36        | 33.53              | 2.0                     |
| 01/27/97              | 150.6             |              |                    | 0.5                     |
| 01/28/97              | 148.0             | 9.75         | 30.48              | 0.0                     |
| 01/29/97              | 148.0             |              |                    | -0.8                    |
| 02/03/97              | 148.0             |              |                    |                         |
| 02/04/97              | 149.3             | 16.76        | 22.86              | 1.0                     |
| 02/05/97              | 150.1             |              |                    | 1.0                     |
| 02/06/97              | 149.7             |              |                    | 1.4                     |
| 02/18/97              | 139.9             | 7.32         | 15.24              | 2.5                     |
| 02/20/97              | 139.9             |              |                    |                         |
| 02/25/97              | 140.0             |              |                    |                         |
| 02/27/97              | 140.0             | 7.32         | 33.53              |                         |
| 03/04/97              | 140.0             | 12.50        | 12.19              | 2.5                     |
| 03/06/97              | 140.0             | 12.19        |                    |                         |
| 03/11/97              | 140.1             | 23.47        |                    | 3.2                     |
| 03/13/97              | 140.0             |              |                    | 2.2                     |
| 03/17/97              | 139.2             | 11.89        | 25.91              | 1.5                     |
| 03/25/97              | 139.0             |              |                    | 3.0                     |
| 04/03/97              | 139.2             |              |                    |                         |
| 04/09/97              | 138.8             |              |                    |                         |
| 04/15/97              | 138.8             |              |                    | 6.5                     |
| 04/25/97              | 138.8             |              |                    | 6.0                     |
| 05/07/97              | 137.7             |              |                    | 8.0                     |
| 05/21/97              | 139.0             |              |                    | 8.0                     |
| 06/01/97              | 139.5             |              |                    | 9.5                     |
| 06/04/97              | 139.0             |              |                    | 8.5                     |
| 06/25/97              | 139.0             |              |                    | 11.0                    |
| 07/01/97              | 138.5             |              |                    | 12.5                    |
| 07/07/97              | 138.5             |              |                    | 14.0                    |
| 07/14/97              | 139.0             |              |                    | 13.5                    |
| 07/22/97              | 139.5             |              |                    | 18.0                    |

Appendix H continued.

| Date     | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|----------|-------------------|--------------|--------------------|-------------------------|
| 07/25/97 | 138.5             |              |                    | 19.5                    |
| 07/29/97 | 139.0             |              |                    |                         |
| 08/05/97 | 138.8             |              |                    |                         |
| 08/19/97 | 138.5             |              |                    | 15.0                    |
| 08/28/97 | 139.0             |              |                    |                         |

<sup>a</sup>Date of capture. p 44

<sup>b</sup>Implant and release date. p 44

Appendix I. Location (rkm), date, velocity, temperature and depth of burbot 2632 as determined by sonic telemetry, Marsh-McBirney current meter and Eagle depth sounder.

| Date                  | Location (rkm)     | Depth (m) | Velocity (cm/s) | Water temperature °C |
|-----------------------|--------------------|-----------|-----------------|----------------------|
| 12/13/96 <sup>a</sup> | 152.6              | 9.14      |                 |                      |
| 12/17/96 <sup>b</sup> | 152.6              |           |                 |                      |
| 12/19/96              | 150.6              | 18.90     | 21.34           | 3.8                  |
| 12/23/96              | 150.9              | 18.65     | 22.86           | 3.5                  |
| 12/26/96              | 150.8              | 18.29     | 3.35            | 2.5                  |
| 12/27/96              | 150.8              |           |                 | 2.0                  |
| 12/28/96              | 150.8              | 21.28     |                 | 1.5                  |
| 01/02/97              | 149.0              | 16.76     | 19.81           | 3.5                  |
| 01/09/97              | 149.1              | 15.45     | 27.43           |                      |
| 01/15/97              | 149.4              | 17.68     | 18.29           |                      |
| 01/22/97              | 150.7              |           |                 |                      |
| 01/23/97              | 150.7              | 14.63     | 24.38           | 2.0                  |
| 01/27/97              | 150.6              |           |                 | 0.5                  |
| 01/28/97              | 149.0              | 15.85     | 19.81           | 0.0                  |
| 01/29/97              | 150.7              |           |                 | -0.8                 |
| 01/31/97              | 150.4              | 18.29     |                 | 1.0                  |
| 02/03/97              | 150.6              |           |                 |                      |
| 02/04/97              | 150.7              | 21.34     | 30.48           | 1.0                  |
| 02/05/97              | 150.7              |           |                 | 1.0                  |
| 02/06/97              | 151.7              | 14.63     |                 | 1.4                  |
| 02/11/97              | 151.5              |           |                 |                      |
| 02/12/97              | 151.9              |           |                 | 1.0                  |
| 02/14/97              | 151.6              |           |                 | 1.6                  |
| 02/17/97              | 152.7              |           | 12.19           | 2.0                  |
| 02/18/97              | 152.7 <sup>c</sup> |           |                 | 1.0                  |
| 02/20/97              | 152.7 <sup>c</sup> |           |                 |                      |
| 02/21/97              | 151.1              |           |                 | 1.1                  |
| 02/27/97              | 150.8              | 26.21     | 25.91           |                      |
| 03/03/97              | 150.5              |           |                 | 2.5                  |
| 03/04/97              | 150.8              | 22.25     | 9.14            | 2.5                  |
| 03/05/97              | 150.6              |           |                 | 1.9                  |
| 03/06/97              | 150.6              | 24.38     |                 |                      |
| 03/10/97              | 150.8              |           |                 | 3.0                  |
| 03/11/97              | 150.6              | 18.29     |                 | 3.2                  |
| 03/13/97              | 150.6              |           |                 | 2.2                  |
| 03/14/97              | 150.6              |           |                 | 1.0                  |
| 03/17/97              | 150.6              | 25.91     | 9.14            | 1.5                  |
| 03/25/97              | 150.8              |           |                 | 3.0                  |
| 04/09/97              | 150.8              |           |                 |                      |
| 04/15/97              | 150.8              |           |                 | 6.5                  |
| 04/25/97              | 150.7              |           |                 | 6.0                  |
| 04/30/97              | 150.8              |           |                 | 6.5                  |
| 05/07/97              | 150.2              |           |                 | 8.0                  |



Appendix I continued.

| Date     | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|----------|-------------------|--------------|--------------------|-------------------------|
| 05/21/97 | 150.3             |              |                    | 19.5                    |
| 07/29/97 | 150.5             |              |                    |                         |
| 08/05/97 | 149.5             |              |                    |                         |
| 08/28/97 | 150.6             |              |                    |                         |

<sup>a</sup>Date of capture. p 46

<sup>b</sup>Implant and release date. p 46

<sup>c</sup>Located 0.7-1.0 km up the Goat River. p 46

Appendix J. Location (rkm), date, velocity, temperature and depth of burbot 93 as determined by sonic telemetry, Marsh-McBirney current meter, and Eagle depth sounder.

| Date                  | Location<br>(rkm) | Depth<br>(m) | Velocity (cm/s) | Water<br>temperature °C |
|-----------------------|-------------------|--------------|-----------------|-------------------------|
| 12/17/96 <sup>a</sup> | 149.6             | 5.49         |                 |                         |
| 12/19/96              | 149.9             | 17.98        | 24.38           | 3.8                     |
| 12/23/96              | 149.6             | 16.46        | 13.72           | 3.5                     |
| 12/26/96              | 149.9             | 16.46        | 3.96            | 2.5                     |
| 12/27/96              | 148.9             |              |                 | 2.0                     |
| 12/28/96              | 149.6             | 17.93        | 1.52            | 1.5                     |
| 01/02/97              | 149.0             | 16.76        | 19.81           | 3.5                     |
| 01/09/97              | 152.7             | 15.24        | 35.05           |                         |
| 01/10/97              | 152.7             |              |                 | 3.5                     |
| 01/15/97              | 153.0             | 21.95        | 28.96           |                         |
| 01/17/97              | 152.8             |              |                 |                         |
| 01/19/97              | 152.8             |              |                 | 2.0                     |
| 01/22/97              | 152.8             |              |                 |                         |
| 01/23/97              | 152.7             | 20.42        | 18.29           | 2.0                     |
| 01/24/97              | 154.0             |              |                 |                         |
| 01/27/97              | 153.4             |              |                 | 0.5                     |
| 01/28/97              | 152.9             | 18.9         | 30.48           | 0.0                     |
| 01/29/97              | 153.0             |              |                 | -0.8                    |
| 01/31/97              | 153.2             | 18.29        |                 | 1.0                     |
| 02/03/97              | 152.9             |              |                 |                         |
| 02/04/97              | 152.7             | 15.24        | 36.58           | 1.0                     |
| 02/05/97              | 152.7             |              |                 | 1.0                     |
| 02/06/97              | 152.7             |              |                 | 1.4                     |
| 02/27/97              | 148.5             | 10.06        | 24.38           |                         |
| 03/03/97              | 149.9             |              |                 | 2.5                     |
| 03/04/97              | 149.6             | 16.46        | 21.34           | 2.5                     |
| 03/06/97              | 149.9             |              |                 |                         |
| 03/10/97              | 149.9             |              |                 | 3.0                     |
| 03/11/97              | 149.9             | 13.72        |                 | 3.2                     |
| 03/13/97              | 150.5             |              |                 |                         |
| 03/17/97              | 150.5             | 21.95        | 10.67           | 1.5                     |
| 03/25/97              | 148.0             |              |                 | 3.0                     |
| 04/03/97              | 149.0             |              |                 |                         |
| 04/09/97              | 149.6             |              |                 |                         |
| 04/15/97              | 149.6             |              |                 | 6.5                     |
| 06/18/97              | 148.5             |              |                 | 12.0                    |
| 07/01/97              | 145.8             |              |                 | 12.5                    |
| 07/07/97              | 143.1             |              |                 | 14.0                    |
| 07/29/97              | 143.8             |              |                 |                         |

<sup>a</sup>Date of capture, implant and release.

Appendix K. Location (rkm), date velocity, temperature and depth of burbot 293 as determined by sonic telemetry, Marsh-McBirney current meter and Eagle depth sounder.

| Date                  | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|-----------------------|-------------------|--------------|--------------------|-------------------------|
| 01/10/97 <sup>a</sup> | 150.2             | 9.14         |                    | 3.5                     |
| 01/14/97 <sup>b</sup> | 150.2             |              |                    | 0.5                     |
| 01/15/97              | 150.5             | 22.86        | 25.91              |                         |
| 01/17/97              | 150.8             |              |                    | 0.5                     |
| 01/23/97              | 150.3             | 9.14         | 3.05               | 2.0                     |
| 01/27/97              | 150.2             |              |                    | 0.5                     |
| 01/28/97              | 150.2             | 9.14         | 18.29              | 0.0                     |
| 01/29/97              | 150.2             |              |                    | -0.8                    |
| 01/31/97              | 150.2             | 7.62         |                    | 1.0                     |
| 02/03/97              | 150.2             |              |                    |                         |
| 02/04/97              | 150.2             | 8.23         | 27.43              | 1.0                     |
| 02/05/97              | 150.2             |              |                    | 1.0                     |
| 02/06/97              | 150.2             |              |                    | 1.4                     |
| 02/11/97              | 150.2             |              |                    |                         |
| 02/13/97              | 150.9             | 21.03        |                    | 1.6                     |
| 02/14/97              | 152.4             |              |                    | 1.6                     |
| 02/17/97              | 152.5             | 8.53         |                    | 2.0                     |
| 02/20/97              | 152.2             |              |                    |                         |
| 02/21/97              | 152.7             | 8.23         |                    | 1.1                     |
| 02/24/97              | 152.7             | 12.19        |                    | 3.0                     |
| 07/07/97              | 154.5             |              |                    | 14.0                    |

<sup>a</sup>Date of capture.

<sup>b</sup>Implant and release.

Appendix L. Location (rkm), date, velocity, temperature and depth of burbot 12 as determined by sonic telemetry, Marsh-McBirney current meter and Eagle depth sounder.

| Date                  | Location (rkm) | Depth (m) | Velocity (cm/s) | Water temperature °C |
|-----------------------|----------------|-----------|-----------------|----------------------|
| 01/14/97 <sup>a</sup> | 150.2          |           |                 |                      |
| 01/19/97 <sup>b</sup> | 155.0          |           |                 |                      |
| 01/22/97              | 154.7          |           |                 |                      |
| 01/23/97              | 154.7          |           |                 |                      |
| 01/27/97              | 154.6          |           |                 | 0.5                  |
| 01/28/97              | 154.5          | 17.07     | 30.48           | 0.0                  |
| 01/29/97              | 154.5          |           |                 | -0.8                 |
| 01/31/97              | 154.5          | 12.19     |                 | 1.0                  |
| 02/03/97              | 154.5          |           |                 |                      |
| 02/04/97              | 154.5          | 16.76     | 22.86           | 1.0                  |
| 02/05/97              | 154.5          |           |                 | 1.0                  |
| 02/06/97              | 154.5          |           |                 | 1.4                  |
| 02/11/97              | 149.7          |           |                 |                      |
| 02/12/97              | 150.9          |           |                 | 1.0                  |
| 02/13/97              | 152.7          | 9.14      |                 | 1.6                  |
| 02/14/97              | 153.0          |           |                 | 1.6                  |
| 02/17/97              | 152.7          | 12.19     |                 | 2.0                  |
| 02/18/97              | 151.8          | 10.06     | 30.48           | 1.0                  |
| 02/20/97              | 152.7          |           |                 |                      |
| 02/21/97              | 152.8          | 14.02     |                 | 1.1                  |
| 02/27/97              | 152.7          |           |                 | 2.5                  |
| 06/04/97              | 133.5          |           |                 | 8.5                  |
| 06/18/97              | 133.5          |           |                 | 12.0                 |
| 08/19/97              | 119.5          |           |                 |                      |

<sup>a</sup>Date of capture.

<sup>b</sup>Implant and release 4.8 km upstream from location of capture.

Appendix M. Location (rkm), date, velocity, temperature, and depth of burbot 276 as determined by sonic telemetry, Marsh-McBirney current meter, and Eagle depth sounder.

| Date                  | Location<br>(rkm) | Depth<br>(m) | Velocity<br>(cm/s) | Water<br>temperature °C |
|-----------------------|-------------------|--------------|--------------------|-------------------------|
| 01/17/97 <sup>a</sup> | 154.0             |              |                    |                         |
| 01/19/97 <sup>b</sup> | 155.0             |              |                    |                         |
| 01/22/97              | 155.0             |              |                    |                         |
| 01/24/97              | 155.2             |              |                    |                         |
| 01/27/97              | 155.3             |              |                    | 0.5                     |
| 01/28/97              | 155.0             | 17.07        | 30.48              | 0.0                     |
| 01/29/97              | 155.0             |              |                    | -0.8                    |
| 01/31/97              | 155.5             | 19.81        |                    | 1.0                     |
| 02/03/97              | 152.9             |              |                    |                         |
| 02/04/97              | 153.1             | 13.72        | 30.48              | 1.0                     |
| 02/05/97              | 153.1             |              |                    | 1.0                     |
| 02/06/97              | 153.1             |              |                    | 1.4                     |
| 02/11/97              | 152.7             |              |                    |                         |
| 02/12/97              | 152.7             |              |                    | 1.0                     |
| 02/13/97              | 152.7             |              |                    | 1.6                     |
| 02/14/97              | 152.5             |              |                    | 1.6                     |
| 02/18/97              | 152.5             | 9.14         | 30.48              | 1.0                     |
| 02/20/97              | 152.7             |              |                    |                         |
| 02/28/97 <sup>c</sup> | 152.7             |              |                    | 2.5                     |
| 03/03/97              | 152.6             |              |                    | 2.5                     |
| 03/04/97              | 152.6             | 7.01         | 27.43              | 2.5                     |
| 03/05/97              | 151.7             |              |                    | 1.9                     |
| 03/06/97              | 152.6             | 8.84         |                    |                         |
| 03/11/97              | 143.1             | 7.62         |                    | 3.2                     |
| 03/13/97              | 143.3             |              |                    | 2.2                     |
| 03/17/97              | 143.3             | 12.80        | 3.05               | 1.5                     |
| 03/25/97              | 142.5             |              |                    | 3.0                     |
| 04/03/97              | 142.8             |              |                    |                         |
| 04/09/97              | 143.5             |              |                    |                         |
| 04/15/97              | 143.7             |              |                    | 6.5                     |
| 04/24/97              | 139.9             |              |                    | 6.0                     |
| 04/30/97              | 132.1             |              |                    | 6.5                     |
| 05/07/97              | 132.1             |              |                    | 8.0                     |
| 05/14/97              | 132.1             |              |                    | 7.7                     |
| 05/21/97              | 132.5             |              |                    | 8.0                     |
| 05/28/97              | 131.5             |              |                    | 8.5                     |

<sup>a</sup>Date of capture.

<sup>b</sup>Implant and release 1 km upstream from capture.

<sup>c</sup>Located approximately 0.7 km up the Goat River.

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